VTT Technical Research Centre of Finland

ManuMaturity

Saari, Leila; Kuusisto, Olli; Häikiö, Juha

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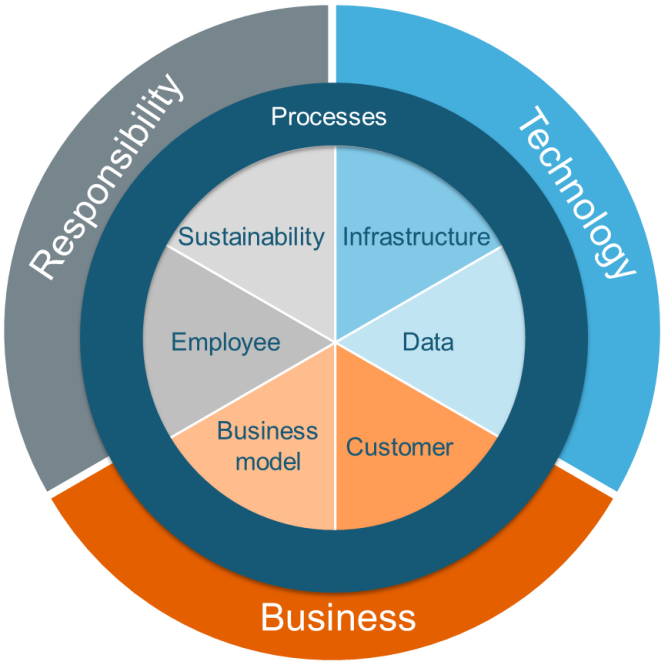
ManuMaturity
- the maturity tool for manufacturing companies to reach beyond Industry 4.0



Leila Saari, Olli Kuusisto, Juha Häikiö
Teknologian Tutkimuskeskus VTT Oy

Abstract

This report presents the both the development steps for agile cognitive industry and the dimensions of the maturity model that were developed for the implementation of ManuMaturity tool. The ManuMaturity tool was implemented to help manufacturing companies to proceed in digitalisation and to reach Industry 4.0 level or even beyond it. The maturity model has three sectors (Business, Technology and Responsibility) and seven dimensions: Customer, Business model, Processes, Data, Infrastructure, Employee, and Sustainability.

With the implemented ManuMaturity self-assessment web tool, a company can discover its own maturity level in addition to strengths and weaknesses with regard to the seven dimensions. The questions and answer alternatives have been formulated to make it possible for the company representatives to complete it independently within 15-20 minutes. The web tool immediately displays the result graph based on the selections of respondent together with the average of all respondents.

The ManuMaturity web tool is available at https://manumaturity.vtt.fi/ for self-assessment of companies. It is free for any non-commercial use.

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1. Introduction

Looking at the industry's agile and sustainable future, the gaze is now shifting past the ongoing development trend, Industry 4.0, and outlining the winning qualities that will follow. There are a number of large-scale projects in Europe that aim to develop the manufacturing industry. VTT Technical Research Centre of Finland Ltd, has also been actively involved in projects and initiatives that explore and develop solutions to support the manufacturing industry's competitiveness. In 2019, VTT published a white paper titled Beyond IoT business and two more in 2020: A review of digitalisation in the Finnish manufacturing SME companies and Sustainable Industry X. Currently VTT is contributing to Sustainable Industry x (SIX)[1], which is the national initiative supercharging Finnish industry performance and sustainable growth through innovation and knowledge.

This report discusses future opportunities and development paths in manufacturing industries. The work is based on ongoing and past projects provides a starting point for developing a maturity model for a future-oriented manufacturing industry - and enables the creation of more precise pathways for progress. The ManuMaturity tool was developed and implemented during VTT's research project called Hyper Agile Cognitive Industry, during 2019.

Demands for agility and cognitivity sue the traditional actors in manufacturing industry. New enabling **technologies** are paving the way for increased flexibility and agility in dynamic manufacturing networks with more intelligent processes. These technologies include e.g. Industrial Internet, robotics, artificial intelligence (AI), 5G, edge computing and IDS[2]. They aim for better customer orientation and productivity but lead also to new ways of working, processes and business opportunities. However, technology alone does not lead to success. Developing and reforming **business models** is a key factor when responding to future challenges. An agile company observes not only customers and their behaviour, but also future trends together with the partners in its network. **Responsibility** has become increasingly important in companies' operations. As environmental awareness increases, the significance of minimization of resource usage and environmental impacts is growing. The optimal interaction between humans and technology is further emphasized when taking AI and robotics into use. In addition, the work content and the roles of employees in industry will also change.

These three sectors (technology, business and responsibility) form the foundation of our agile cognitive manufacturing industry maturity model (Figure 1). By looking at their activities through these dimensions, the manufacturing industry can map their capabilities and identify development targets when reaching Industry 4.0 and even beyond.

In the next section the maturity model of agile cognitive industry will be described. Section three contains the dimensions, the related questions and response options exploited in the tool. The fourth section carries the tool itself and the fifth one closes this report.

[1] https://www.six.fi/
[2] https://www.internationaldataspaces.org/category/ids-en/

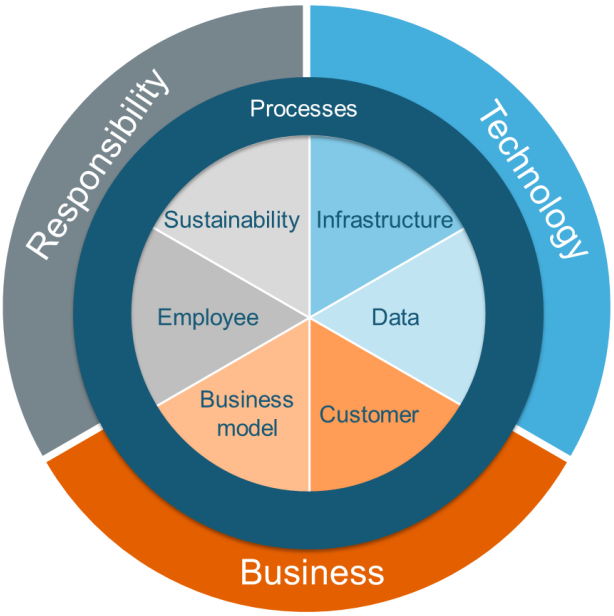

Figure 1: Seven dimensions in three sectors: technology, business and responsibility.

2. Maturity model and its levels

Maturity as a measure to evaluate the capabilities of an entity has become popular since the Capability Maturity Model (CMM) was proposed and has been proven in practice on Software Engineering domain. Usually in a CMM there are five maturity levels: Initial, Managed, Defined, Quantitatively Managed and Optimising.

Next we will briefly introduce the development levels that were generated based on the literature around Industry 4.0. The levels guided us in the development of the tool. The levels were: i) traditional factory, ii) modern factory, iii) agile factory, iv) agile cognitive factory, and finally v) agile cognitive industry (Figure 2).

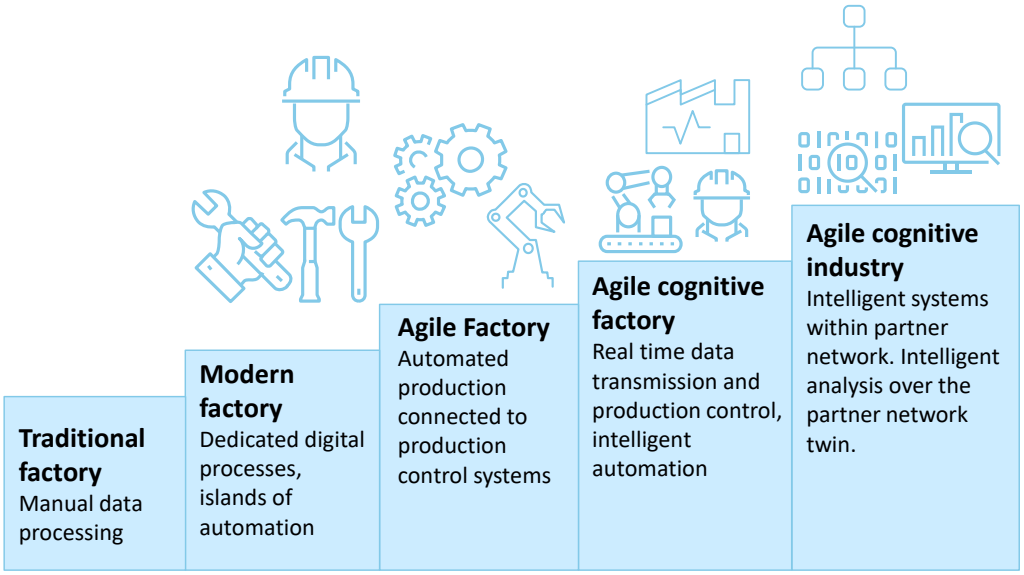

Figure 2: The development steps towards agile cognitive industry were utilized while designing the response options in the ManuMaturity tool.

At the first level there is a ***traditional factory*** where data processing is still completely manual except for office programs. Production uses traditional machines and equipment that do not produce digital data as separate factors of production. Workers' work consists mainly of physical repetitive tasks. The company sells mainly capacity/ subcontracting, not own products.

The ***modern factory*** already has separate digital processes, but the combination of data is done manually. The factory has automation islands and robots. Additional income is gained from consulting and customizing the use of products. In the modern factory digitalization is siloed, as there are some digital interfaces between employees and machines, but not between systems. The company has partially automated production but with limited flexibility. Work is a combination of physical and knowledge-based tasks. The company sells products and supplementary services such as product design and/or technical support.

The ***agile factory*** features automated production, such as flexible manufacturing systems (FMS cells). The company gathers up-to-date information both from the production process and from product life cycle, and integration of it takes place mainly automatically. Automated production and/or flexible robotic systems are reconfigurable and connected to production control systems. Intelligent systems and/or robots allow employees to focus on more cognitive tasks, e.g. planning and monitoring, as repetitive tasks have been automated. The company offers product-related supplementary services such as predictive maintenance and updates.

In an ***agile cognitive factory***, the information moves in real-time. Agile and efficient production is based on real-time production control of the supply chain, which takes care of rerouting, retiming and replanning when needed. Intelligent automation cooperates with workers in performing complex tasks. The real-time control system has remote interfaces. The company can act as performance partner and bears (at least partially) the responsibility for the actual performance of the product.

Agile cognitive industry is a level where products and services are manufactured and produced in agile and tailored (even one-off) way based on demand. Procurement of materials is forecasted including the whole supply chain and manufacturing is planned based on predicted demand. Customers can plan and order personalised products with possible services in cooperation with the partner network. They can be upgraded when in use. Agile and efficient production is enabled by intelligent AI based systems that interact in the partner network. Intelligent analytics verifies and prepares the data in real-time before they are used in the decision-making in the partner network. Complex processes are performed without regular human intervention in the partner network.

The next section carries the dimensions, related questions and response options that are implemented in the ManuMaturity tool.

3. Dimensions, related questions and response options

Our model has three sectors and seven dimensions as illustrated in Figure 1. The dimensions are: Customer, Business model, Processes, Data, Infrastructure, Employee, and Sustainability. The dimensions, related questions and response options (of the tool) are highlighted in (Figure 3) and will be introduced in following paragraphs.

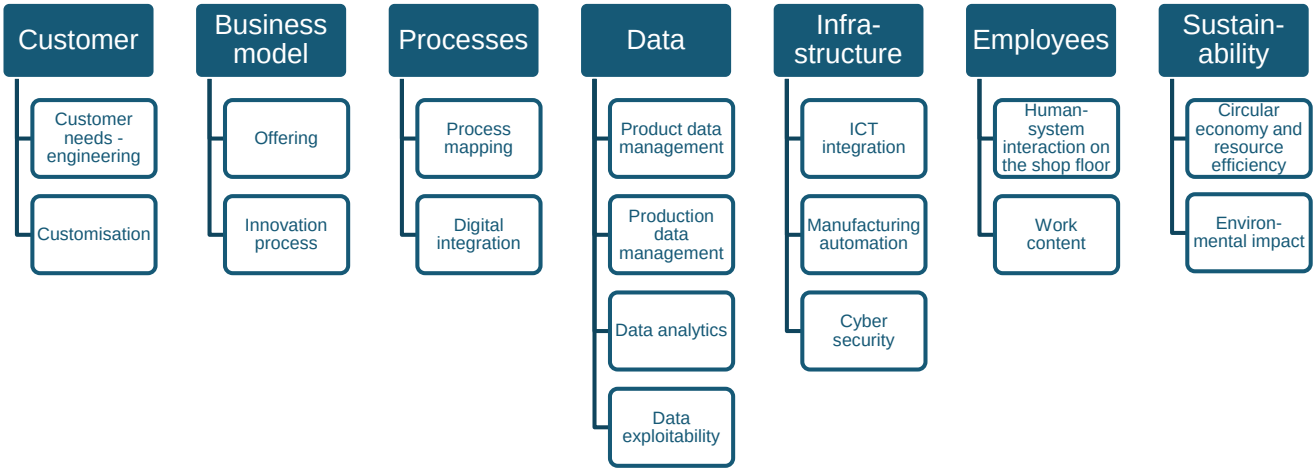

Figure 3: The dimensions and topics of related questions of the ManuMaturity tool.

Customer

Customer needs - engineering

How customer needs and requirements are gathered and exploited?

- ✓ Order and sales history are utilized in product engineering.
- ✓ The requirements and feedback of most important customer groups are included in product engineering.
- ✓ Customer requirements, feedback and product usage and service data are gathered and exploited in product and service engineering.
- ✓ Customer requirements, feedback and product usage pattern data is kept up-to-date to be exploited in product and service engineering within the supply chain.
- ✓ Partner network uses advanced (e.g. artificial intelligence, AI) methods for product and service engineering to gain optimal customer experience.

Customisation

How products can be customised?

- ✓ Customers can select stock items from existing product families.
- ✓ Customers can select from predefined product options (e.g. add-ons/accessories).
- ✓ Customers can configure modular products and define parameters from a given range with the aid of IT system.
- ✓ Customers can co-configure and visualise products (before ordering) based on their needs.
- ✓ Customers can plan and order personalised products with possible services in coopera-tion with the partner network. Products can be upgraded when in use.

Business model

Offering

What is your company selling?

- ✓ Company is selling capacity (e.g. engineering, production or service capacity).
- ✓ Company is selling products. Additional profit is gained from e.g. engineering and tech-nical support.

- ✓ Company provides added value through product-related services (e.g. maintenance and upgrades).
- ✓ Company is not selling products but the performance of those. It is acting as a performance partner taking at least partly responsibility for the actual performance (e.g. capacity or uptime).
- ✓ Company acts as a value partner, whom customer pays for the actual outcome, which can be flexibly scaled based on usage patterns or predictive demand.

Innovation process

How innovations are mastered?

- ✓ There is no innovation process. Innovations emerge (pop up) ad hoc.
- ✓ Innovations are discovered by a limited group of people. Innovations are sought only against specific challenges.
- ✓ In-house innovation process exists and new ideas are gathered. R&D partner(s) are invited in case they have special knowledge or resources.
- ✓ Customers and supply chain are included in innovation and foresight processes. Agile interaction with R&D partner network provides knowledge required to implement innovations.
- ✓ Partner network co-creates disruptive innovations and shared vision for the future. The network is able to expand beyond its own competences and capabilities.

Processes

Process mapping

What is the status, definition, and implementation of processes in your organisation?

- ✓ The need to standardize working methods and define processes has been identified. There is occasional repeatability of working methods, e.g., in projects
- ✓ Processes have been identified, defined, and documented, by, for example, function or team.
- ✓ Internal processes for different functions have been identified and defined comprehensively and in a managed way. Processes are assessed regularly and developed when needed.
- ✓ Process mapping includes relations to supply chain network.
- ✓ Processes also cover partner networks and the customer interface.

Digital integration of processes

How is digitalization exploited in the integration of processes?

- ✓ Digital technology is not utilised in the organisation except for office tools (e.g. word processing and spreadsheets).
- ✓ Some processes have been integrated (e.g. engineering and manufacturing).
- ✓ Internal processes and interfaces between different systems have been defined and standardized.
- ✓ Current and correct information over the supply chain is available digitally and in real time to those who need it.
- ✓ Processes of the partner network actors have been integrated. Joint digital platforms are in use.

Data

Product data management

How product data is collected and shared?

- ✓ No digital product data is used. Data is processed manually into usable form of information.
- ✓ Discrete digital product data exists in silos. Manual combination of data from different product lifecycle phases is required.
- ✓ Up-to-date product data from various product lifecycle phases (such as use and service data from set of products) is collected.
- ✓ Secure real-time product data is collected through product lifecycle phases and shared over the supply chain when relevant.
- ✓ Secure processes and interfaces for collecting and sharing real-time product data are implemented in partner network covering product lifecycle phases.

Production process data management

How production process data is collected and shared?

- ✓ No digital production process data is used. Data is processed manually into usable form of information.
- ✓ Discrete digital production process data exists in silos. Manual combination of data from different sources is required.
- ✓ Up-to-date production process data from various sources is collected. Manual combination of data from different sources is not required.
- ✓ Secure real-time production process data is collected and shared within the supply chain.
- ✓ Secure processes and interfaces for collecting and sharing real-time production process data in partner network have been implemented.

Data analytics

How data is analysed?

- ✓ No automated data processing or analysis. History data is analysed manually: What has happened?
- ✓ The most important production processes are digitally monitored, data is stored and some urgent border values are set. Simple diagnostics explain: Why did it happen?
- ✓ Some data analytics is integrated in decision support systems for e.g. predictive production planning, maintenance or optimisation. Analytics gives an insight: What will happen?
- ✓ Some rule based analytics for predicting and supporting human is used. Analytics proposes: What should be done?
- ✓ Data analytics is integrated within decision support systems in the partner network. Autonomous decision making based on e.g. machine learning methods is used. The decisions are transparent and the rationale of each decision can be traced.

Exploitability of data

How the exploitability of data is ensured?

- ✓ Data is manually collected from different sources, is incomplete, has errors and/or various formats. Data needs a lot of manual pre-processing before it can be analysed.
- ✓ Some discrete digital data is existing, but its quality varies, e.g. the formats or meanings are not unified. Data needs some manual pre-processing before it can be analysed.
- ✓ Continuous data from heterogeneous sources is available and its meanings, formats, and threshold values are described. Pre-processing of input data is automated.

- ✓ Real-time data is available. Common metadata models, communication standards and interfaces provide transparency over the supply chain. AI pre-processes and validates the input data.
- ✓ Intelligent analytics (e.g. AI) validates and pre-processes the incoming data in real-time before it is exploited in decision making of partner network. Machine learning is harnessed to update the metadata model based on input data.

Infrastructure

ICT integration

How are order, product and production data handled?

- ✓ There are no dedicated ICT tools for processing order, product and production data, but office tools, e.g. spreadsheet and word processing are used.
- ✓ ICT infrastructure is fragmented and in-house. Order, product and production data exist in separate systems. Data is combined (mainly) manually.
- ✓ Integrated in-house ICT infrastructure enables management and visualisation of orders, products and production.
- ✓ Product and production models and real time data are integrated into real-time production planning and control system(s). This enables operative simulation and performance optimisation..
- ✓ Common ICT infrastructure and processes enable real-time data exchange in the partner network. This enables transparency and optimisation of network actions.

Manufacturing automation

How agile production is enabled?

- ✓ Company has no automation solutions. Humans takes care of the agility. Machine tool settings can be changed manually.
- ✓ Company has partially automated production (manufacturing) cells, CNC machines and/or dedicated robotic systems, which have limited flexibility.
- ✓ Company has automated production, flexible manufacturing cells (FMS) and/or flexible robotic systems, which are reconfigurable and connected to production control system(s).
- ✓ Agile and efficient production is based on real-time production management of the supply chain that handles the re-routing, re-scheduling and planning of orders when necessary. Physical layouts can also be easily reconfigured.
- ✓ Agile and efficient production is enabled by intelligent systems that interact in the partner network. Industrial infrastructure of the partner network support on-demand production and resource sharing.

Cyber security

How systems, networks and programs are protected from digital attacks?

- ✓ Some discrete security tools and processes are implemented.
- ✓ Access control and authentication processes are implemented by e.g. passwords and logins.
- ✓ Secure communication protocols are exploited. Continuous in-house monitoring provides both security status and statistics.
- ✓ Security policies are embedded within the supply chain. Real-time intelligent analytics detects anomalies and predictive threat prevention is enabled by deep learning.
- ✓ Critical infrastructure is secured and monitored in the partner network. Cyber security mechanisms such as “honey pots” or “tar pits” are exploited to track attackers’ activity and to defend against cyber threats.

Employee

Human-system interaction on the shop floor

How machines/systems interact with employees?

- ✓ Manual interaction between employees and machines.
- ✓ There are some digital interfaces between employees and machines (automation islands). Production automation and/or robotic systems can perform simple tasks.
- ✓ Intelligent systems and/or robots enable employees to focus on cognitive tasks (e.g. monitoring and planning). Information exchange on process related task are at least partially automated.
- ✓ There is a real-time control system with remote user interfaces. Intelligent automation (e.g. cobots) co-operate with employees to perform complex tasks.
- ✓ Complex processes within the partner network are performed without regular human intervention.

Work content

Where is the focus of work?

- ✓ Employee's work consists mainly of physical repetitive tasks.
- ✓ Employee's work is a combination of physical and knowledge-based tasks.
- ✓ Employee's work is mainly monitoring and optimisation with a lot of data available. Digital, e.g. AR and VR based applications are supporting employees at work.
- ✓ Employees are supervising the production and co-design agile production processes (of supply chain). E.g. machine vision systems control the quality of production in real-time.
- ✓ Employees (human intelligence) can take over in critical situations of networked production (e.g. equipment failures).

Sustainability

Circular economy, resource efficiency

How resources are used?

- ✓ No energy and/or material consumption reduction actions have been implemented.
- ✓ The use of virgin raw materials, water and energy has been minimised at machine, process and company level; limiting inputs.
- ✓ Company is limiting inputs and reducing outputs: The use of virgin raw materials, water and energy has been minimised. The amount of waste is minimised and side streams are utilized. Life cycle approach is applied (e.g. ISO 14040-44).
- ✓ Environmental impact assessment is a driving force of product development (Eco Design). Durability and upgradability of products is promoted. Management of materials is based on a cyclical pattern of use (reuse, recycle and re-manufacturing).
- ✓ Circular economy business models are implemented in order to close the material loop and reduce the environmental footprint taking customer and society expectations explicitly into account in the partner network.

Environmental impact

How environmental impacts are considered?

- ✓ Operation of the company fulfils the environmental regulation.
- ✓ Solutions for decreasing the environmental emissions and wastes are sought and piloted.
- ✓ Solutions for decreasing the environmental impacts are developed. Lifecycle thinking covering the supply chain based on standardised assessment (ISO 14040-44, ISO 14067) is applied to improve environmental performance.

- ✓ Environmental impact assessment is the driving force of product and production development. Environmental criteria are used in selecting suppliers. Environmental sustainability is transparently and publicly communicated.
- ✓ Predictive decision making of environmental impacts is performed over the partner network. Online lifecycle assessment enables environmental impacts to be taken into account in real-time process optimisation and product-specific footprint calculations.

4. The self-assessment tool is available for the manufacturing industry

The developed maturity model serves especially those manufacturing companies with vision to reach beyond Industry 4.0. The ManuMaturity web tool is available at https://manumaturity.vtt.fi/ for the self-assessment of companies. It helps companies to recognize their maturity level. It contains the most essential viewpoints and dimensions of agile cognitive industry. For each dimension (Figure 2, inner sectors) there is a question and five response alternatives at different maturity levels to choose from. Based on the answers, the public web tool calculates the average for each dimension and displays the situation of own and other respondents as a graph. If control group information is needed e.g. based on branch or size turnover and/or headcount, or if you want to find out how to proceed, please contact the authors at VTT. The test takes about 15-20 minutes.

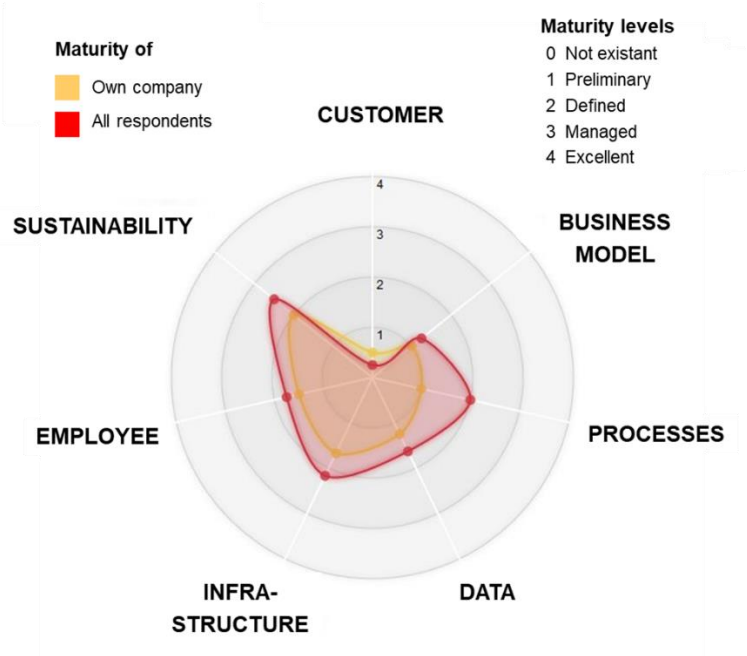

Figure 4: The diagram shows digital maturity of the organisation and reference values of all organisations. It is also possible to form selected control groups (based on branch, turnover and/or number of employee).

5. Conclusion

With the VTT's ManuMaturity self-assessment tool, a manufacturing company can discover its own maturity levels of each dimension in addition to the strengths and weaknesses with regard to the seven dimensions. The questions and answer alternatives have been formulated to make it possible for a company representative to complete the self-assessment independently within 15-20 minutes.

To discover the maturity and potential development path of reaching Industry 4.0 or even beyond, visit https://manumaturity.vtt.fi/

More information

Leila.Saari@vtt.fi

Olli.Kuusisto@vtt.fi

Juha.Haikio@vtt.fi